

# NOTHING BUT STONES? A REVIEW OF THE EXTENT AND TECHNICAL EFFORTS OF PREHISTORIC STONE MULCHING ON RAPA NUI

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## INTRODUCTION

The distribution of stones on the surface of gardens to increase yield is called stone mulching or lithic mulching. This technique was applied in prehistoric times on almost all continents, but was very limited in space and time and adapted to local conditions (Lightfoot 1994). It was even more restricted to arid and semi-arid ecosystems of South America, North America, Africa, and in the Near East. Only a few applications of the technique are known from sites with a humid climate, e.g. New Zealand. Lightfoot (1994) describes the technique as a specific niche adaptation for sites which otherwise could not be used horticulturally or agriculturally. While several advantages and disadvantages of stone mulching in prehistoric times are known, the development of the technique is still widely unknown (Lightfoot, 1994:178). Some of the factors which may raise crop yields have been identified in experiments (Fairbourn 1973). Stone mulching:

- reduces the effects of wind and evaporation
- increases the soil moisture content
- reduces splash erosion
- reduces surface runoff by increased surface roughness
- protects against wind erosion and water erosion
- stores heat and thus reduces the amplitude between the lowest and highest temperatures during the day
- intensifies the growth of the sprouts and roots of cultivated plants by mechanical resistance of the stones
- suppresses the growth of weeds

The preparation, transport to, and dispersion of stones on cultivated land was an enormous effort. Additionally, each stone had to be moved before and after planting and harvesting.

As mentioned above, stone mulching techniques were applied in prehistoric New Zealand (Lightfoot 1994). Using the term *maori plaggen soils*, McFadgen (1980) describes the insertion of stones and sand in arable land where taro and sweet potatoes were grown. Stevenson and Haoa (1997), Stevenson et al. (1999; 2002), and Wozniak (1999) made detailed studies of the use of stones in agriculture and horticulture on Rapa Nui. Stone mulch on the surfaces of prehistoric gardens or fields near the northwest coast of Easter Island was analyzed by Wozniak (1998; 1999; 2001). At *Te Niu*, stone diameters of 5 cm to 20 cm were found to dominate at the surface. Underneath, only a few stones were found. The studies show that both the number and size of the stones decrease with depth. Stones in layers of 20 to 40 cm thick were observed by Wozniak in the northwest of the island. Below these

layers was much evidence of cultivation, such as a loose soil structure, planting pits, coral fragments, mollusk shells, ashes, and charcoal material – all brought into the soil as manure (Wozniak 2001). Stevenson et al. (1999; 2002) distinguish between six techniques of stone-based agriculture, three of which may be called stone mulching:

- stone coverage at the surface (“veneer surfaces”),
- cultivated soils where stones were mixed in to a depth of 30 cm to 50 cm (“mulched soils”), and
- a combination of a regular stone cover with concentrated accumulations of stones (“stacked boulder concentrations”).

Basalt outcrops in the vicinities of the cultivated areas were identified as sources of the stones. Probably stone mulching was introduced after approximately cal AD 1400 to reduce weather risks and to increase yields – possibly in connection with the introduction of the sweet potato, an increasing population, and the expansion of settlements and ceremonial complexes (Stevenson et al. 2002). The authors assume that sweet potatoes, taro and yam were cultivated in stone-mulched land.



Figure 1. Investigations of stone mulching techniques.

## RESEARCH QUESTIONS

Some questions about the use of the technique of stone mulching on Rapa Nui still have to be resolved. Where on Rapa Nui is the stone cover really man-made, and where is it the result of natural processes? Where on the island was the method of stone mulching used? Where was gardening practiced? Which stone densities are common? Can we estimate the dimension of human labor for the production and distribution of stones on the surface of Easter Island?

To answer these questions, the concentration and the size of the stones at the soil surface were recorded by the authors at more than 500 locations spread over Easter Island.

## STONE COVER – NATURAL OR MAN-MADE?

By which processes were millions of stones distributed on the garden soils of Easter Island?

The upslope areas of Maunga Terevaka and Rano Kau are covered with natural regoliths with densities of less than 10,000 stones per hectare cropping out at the present soil surface. The processes that may have spread stones, such as overland or gravity flow, can be excluded at most other sites, as none of the specific characteristics to be expected, e. g. in bedding, roundness or grain-size spectrum are found outside of the areas pre-mentioned.

Many characteristics of the widely spread dense surficial stone cover point towards a man-made origin. Stones at the soil surface

- are mostly spread regularly
- have similar diameters and volumes at individual sites
- are either angular and hewn (made of fresh basalt quarried at nearby valley rims) or they are somewhat round with a rough surface, being core stones extracted from weathering profiles
- are mostly situated on loamy or clayey soils which contain no or only very few stones, and which show evidence of having been used horticulturally, such as traces of digging or tubers of cultivated plants still preserved
- are situated, with a few exceptions only, on the present soil surface, sediment-covered stone layers being a rare exception
- are located at sites with different slopes, curvatures, and expositions, preferentially on concave foothills above the cliffs near the south and north coast, and at the bottom of the many narrow valleys
- are sometimes spread at sites above where no bedrock is exposed near the surface and thus no natural source of the stones exists
- are normally spread in a thin layer, and
- cannot be explained by selective removal of fines

Several pits dug by the authors confirm, for most parts of Rapa Nui, the total absence of stones or low concentrations only (less than 10% of the total soil volume) in the upper three or four decimeters of formerly cultivated garden soils underneath the surficial stone covers. Most of the few stones that were found were much smaller than those on the surface. Some of the stones found in the cultivation layer were probably brought in from the surface by digging and planting activities and were not – unlike most of the stones – put back on



Figure 2. Typical stone coverage in the south of Easter Island



Figure 3. Low stone content below the soil surface (location is the same as in Figure 2)

the surface. The strong decrease of stone content with increasing depth as identified by Wozniak (1999) is confirmed by our study.

## WHEN DID THE RAPANUI PRACTICE STONE MULCHING?

The beginnings of stone mulching cannot yet be exactly reconstructed for Easter Island. During the long-lasting period of horticultural use of the palm forests (cf. Mieth et al. 2002; 2003) and in the ensuing early period of palm tree clearing (cf. Mieth and Bork 2003, Bork and Mieth 2003) the technique of stone mulching was obviously unknown. Neither on the widely-spread garden surfaces within the former palm forests,

nor on the layer of charcoal marking the period of clearing, nor below layered sediments (cf. Mieth et al. 2002; 2003) was a single mulched stone layer found – neither on the Poike Peninsula nor at Rano Kau, at Rano Raraku or any other location.

The study of a soil pit in the southwestern foothills of Maunga Orito yielded evidence of a late prehistoric application of the technique of stone mulching. A dense stone layer there covers most of the present soil surface surrounding the pit. Underneath, sediment a few tens of centimeters thick was found, containing traces of planting pits and sickle-shaped bandings of ashes and charcoal. The latter can be interpreted as relicts of fire pits and *umu* (earth ovens). The sediment is totally stone-free. Three AMS-radiocarbon dates of charcoal from the fire-pits, *umu* and the surrounding planting pits yielded the following results:

- charcoal excavated 13 cm below the present surface of a planting pit: conventional radiocarbon age: BP 114±21, calibrated radiocarbon age: 2σ cal AD 1682-1734 [28.6% probability], 1807-1903 [55.3%], 1905-1930 [11.4%]; KIA 17118
- charcoal excavated from a fire pit, 40 cm below the present surface: BP 177±18, 2σ cal AD 1665-1683 [15.3%], 1733-1784 [47.7%], 1789-1808 [13.4%], 1928-1955 [19.1%]; KIA 17116
- charcoal excavated at 63 cm below the present surface from a planting pit: BP 148±18, 2σ cal AD 1672-1689 [16.2%], 1723-1779 [38.2%], 1798-1814 [9.5%], 1832-1879 [12.4%], 1915-1944 [19.1%]; KIA 17117.

From these dates, it appears that sedimentation, planting, and cooking most likely did not occur before the second half of the 17<sup>th</sup> century, probably after 1700 and before the 1860s. Stone mulching must have been practiced in this period as well. The stone layer itself cannot have originated from the upslope areas at Maunga Orito, where obsidian was cut and finished, as the stone mulching layer mainly consists of basalt.

During his visit of Easter Island in 1774, the stone-covered surfaces of Easter Island caught the attention of an early European visitor, Georg Forster (1983, reprint), a German scientist with James Cook. He reported that "the soil was covered everywhere with stones of different sizes" and that stones had been removed along narrow footpaths. Forster mentioned that plantations were covered with grass that had been torn out from between the stones – an indication of the combined use of stone mulching and organic mulching techniques.

Stone mulching probably ended or was at least extremely reduced in the 1860s when the number of inhabitants of the island declined from several thousands to only 110. After the dramatic reduction of nutritional needs, only a few sites continued to be used horticulturally or agriculturally during the late 19<sup>th</sup> and early 20<sup>th</sup> century. Today the technique of stone mulching has been forgotten on Rapa Nui. Modern agriculture, cattle and horse grazing are hindered by the dense stone cover on the surface of the island.

The time of development or adaptation of the technique on Rapa Nui remains unclear. But the *maximum* duration of the period during which stone mulching was practiced can be given with a sufficient probability:

- There are no indications for the use of the technique before approximately cal AD 1300 (from studies on the Poike peninsula and at other sites)
- The application of the technique ended most probably in or before the 1860s when the population density was at its minimum

Thus a maximum duration of the stone mulching period of about 560 years can be assumed, but a distinctly shorter period is more likely.

#### STONE MULCHING: INNOVATION TRIGGERED BY ENVIRONMENTAL DISASTER?

Palm trees protected the garden soils during the early period of sustainable land use on Rapa Nui (Mieth and Bork 2003). The crowns of the palm trees prevented high wind velocities and thus reduced wind erosion at the soil surface. Compared to exposed surfaces, the soil dried out much more slowly and far less intensively. Leaves of wind-sensitive plants such as *Musa sp.* (*maika*, banana) were well protected in the dense palm forest. Runoff generation and water erosion were prevented by interim storage of rainwater on plant surfaces and by the high infiltration capacity of the well-structured garden soils. Our geomorphological, pedological, and palaeo-ecological studies have revealed the wide range of positive functions of the palm forest (Mieth et al. 2002; 2003). There was no need for mulching and it was not practiced in the palm forest-protected fields.

Clearing of the palm forests removed the excellent protective cover. (cf. Flenley and Bahn 2003, Mieth and Bork 2003, Bork

and Mieth 2003). The frequent strong winds began to blow fertile soil particles into the ocean and desiccated the exposed soils. Heavy rainfall further eroded the fertile topsoil in the cleared areas, decreasing yields.

Stone mulching techniques had to be introduced to improve soil protection and to preserve the remaining soil fertility. The new technique spread over the island. It was not practiced where the fertile soils had already been completely eroded after clear-cutting, as in the easternmost (Poike Peninsula) and the southwestern parts of the island (upper slopes of Rano Kau), and also not where young and still unweathered rocks were exposed.

It is most likely that large and solid parts of plants (branches, roots and stems of bushes and trees) were not available in sufficient quantities for mulching. Thus stones had to be used to stabilize the soil surface – another argument for the late introduction of stone mulching techniques, when wood had become scarce and desiccating topsoils and soil erosion by wind and water had become major concerns of the island society.

#### EXTENT OF STONE MULCHING

The technique of stone mulching was not employed on:

- Poike Peninsula and the upper slopes of Rano Kau (area of approximately 20 km<sup>2</sup>)
- middle and upper slopes of many side volcanoes (approximately 6 km<sup>2</sup>)
- extended younger lava fields with their absence of weathered rocks (approximately 6 km<sup>2</sup>)
- the cliff (approximately 6 km<sup>2</sup>)
- higher slopes of Maunga Terevaka (approximately 25 km<sup>2</sup>), and
- several small isolated areas (approximately 27 km<sup>2</sup>)

Table 1: The extent of stone mulching on Easter Island – synopsis of statistical data and assumptions made in the text.

Number of sites investigated	> 500
Extent of the stone mulching area on Rapa Nui	76 km <sup>2</sup>
Total number of mulching stones	1,140,000,000
Total weight of mulching stones	2,150,000 t
Maximal stone density on mulched areas	> 1,700,000 stones per ha
Average stone density on mulched areas	150,000 stones per ha
Average stone density on Rapa Nui	60,000 stones per ha
Average transport distance (from a quarry to a garden)	65 m
Maximum duration of stone mulching	~1300 – 1860 AD
Assumed duration of stone mulching	~1460 – 1860 AD
Persons permanently involved in the preparation of stones	~45
Persons permanently involved in the transport of stones	~45
Persons permanently involved in the distribution of stones	~45
Working days per year	300
Daily performance of stones transported per person	400 kg (20 x 20 kg)
Total distance covered per person and year	780 km
Total distance covered during 400 years of stone mulching	14,000,000 km



Subtracting the total un-mulched area (90 km<sup>2</sup>) from the island's total surface (166 km<sup>2</sup>) leaves a stone-mulching area of 76 km<sup>2</sup>. Measuring the stone-mulched areas themselves led to almost the same figure.

The mulching-stone density per square meter was determined at more than 500 sites. The sites studied are close to the southern coast between Ahu Vinapu and Tongariki, in the North between La Pérouse and 'Anakena, near the western coast, in the center of the inland (e.g. in the surroundings of Fundo Vaitea), and at several other places.

Additionally, at 20 representative transects, (each 20 m long), the number, diameter, volume and weight of all stones as well as the degree of surface cover by stones were determined. The average distances between stone-mulched gardens and the nearest local basalt outcrops were also recorded.

The intensity of stone mulching density varied significantly: from about 8,000 stones per hectare (0.8 stones per m<sup>2</sup>) to more than 1,700,000 stones per hectare (170 stones per m<sup>2</sup>), or from less than 1% to more than 80% of stone cover on the soil surface. Stone densities between 60,000 and 400,000 per hectare (9-25% stone coverage) prevail. On average, 150,000 stones were deposited per hectare of soil surface (15 stones per m<sup>2</sup>).

The average diameter of an individual mulching stone is 12 cm. In a random sample, the average stone diameter varied from 9 cm to 14 cm. The largest stone weighed was more than 200 kg, but even heavier stones were deposited at other areas.

Multiplying the island's stone mulching area (76 km<sup>2</sup>) by average stone density (150,000 stones per hectare) yields a huge figure: around 1.14 billion stones were spread on the soils of Rapa Nui during a few centuries. What effort was needed for placing 1.14 billion mulching stones?

On average the stones were transported over a distance of 65 m from numerous local basalt outcrops to the neighboring mulch gardens. What weight might have been moved by a man day by day over that average distance for many years? We assume that one worker carried 20 kg of stones during each transport, doing so 20 times a day. Thus 400 kg could be transported by one man per day from a quarry to a stone-mulched garden. We further assume that each man worked for an average of over three decades for 300 days per year. Thus approximately 120,000 kg or 120 tons of stones could be transported by one man per annum, or 3.6 million tons over three decades.

The total weight of all stones mulched on Rapa Nui amounts to more than 2.15 billion kg or 2.15 million tons. A division of this mass by a supposed annual transportation load of 120 tons is equal to approximately 18,000 working years. During an assumed period of 400 years in average 45 persons should then have been occupied with transporting stones. A comparable number of persons might have been involved in preparing the stones at the basalt outcrops, and the same number again may have been engaged in the distribution of the stones in the gardens. Digging small pits and planting would also have involved much effort.

Thus, a significant portion of the population must have been involved in stone mulching and horticulture. Bahn (1993) and Flenley and Bahn (2003) assume an average population number of approximately 3,000 for the period from the

15<sup>th</sup> to the early 19<sup>th</sup> century. Thus at least 5% of the total population or 15 to 20% of the adult males may have been engaged in preparing, transporting and spreading of stones. A transportation mass of 400 kg of stones per day, 300 days per year over 30 years certainly represents the maximum effort of one human being. If the technique of stone mulching were applied on Easter Island over less than 400 years (as is likely), an even larger number of men would have had to do the work. Or have average population numbers for Rapa Nui been underestimated?

For statistic-lovers yet another interesting figure: If 20 kg stones were transported over an average distance of 65 m, from the total weight calculated above, a total of 107 million trips would have been made. Taking into consideration the return back from the gardens to the basalt outcrops without a load, men would have walked a distance of almost 14 million km total (equivalent to 330 times the length of the equator). An average person would have walked 34,400 km during an assumed 30-years' working life, and for half of this distance transporting a weight of 20 kg of stones.

## CONCLUSIONS

The dense palm forests of Easter Island, which had been used horticulturally up to the 9<sup>th</sup> or 10<sup>th</sup> century, had been completely removed by the 17<sup>th</sup> century, and with it any protection of the soils and plants against wind and water erosion. Techniques to protect the soil from erosion had to be developed by the inhabitants of Easter Island. Thus stone mulching was introduced to reduce soil loss. For centuries, before AD 1860, stone mulching must have been an important activity in the gardens of the Rapanui, the native population of Easter Island. More than a billion stones were carried from numerous basalt outcrops to the gardens. Evaporation and soil erosion was reduced by stone mulching, and the fertility of the soils was partly preserved. Based on more than 500 sites it appears that the total area where stone mulching employed was 76 km<sup>2</sup>, the average stone mulching intensity was about 150,000 stones per hectare, and the average distance from quarry/source to garden was 65 m. For about 400 years an estimated 135 persons at least must continuously have been involved in the preparation, transport and distribution of the total of 1.14 billion stones.

Some of the assumptions made will remain purely theoretical. But there is no doubt that the technique of stone mulching was an important development and time-consuming activity of the society of the Rapanui. Stone mulching reached a degree of perfection and of intensity unique on earth. Only high yields or positive environmental effects could have justified the enormous efforts involved in stone mulching. After a long period of expansion, population growth and concomitant reduction of soil and wood resources, an enormous pressure to produce a sufficient food supply obviously required a re-orientation of horticultural techniques.

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